GOES-R Product Training Document

for the
GOES-R Proving Ground
Aviation Weather Testbed 2013 Summer Experiment

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WRF/NAM Simulated ABI – Quick Guide
Part I: Water Vapor Bands

What is the WRF/NAM Simulated ABI?

Synthetic satellite imagery provides forecasted radiances in an intuitive display with which users are already familiar, while simultaneously allowing a glimpse into next generation satellite capabilities. Bands and band differences are generated from both the 4 km NSSL WRF-ARW and 4 km NAM Nest models, and can be used to identify specific atmospheric features and monitor the evolution of synoptic and mesoscale systems.

What water vapor bands are available?

NSSL WRF-ARW	**Description**
GOES-R Band 8 (6.19 µm)	Upper-level Tropospheric Water Vapor
GOES-R Band 9 (6.95 µm)	Mid-level Tropospheric Water Vapor
GOES-R Band 10 (7.34 µm)	Mid to Low-level Tropospheric Water Vapor
NAM Nest	
GOES-13/15 Band 3 (6.5 µm)	Mid to Upper-level Tropospheric Water Vapor

How can simulated imagery be used prior to GOES-R?

Comparing the morning simulated imagery with observed imagery can aid in determining if the model has similar timing and location of synoptic and mesoscale features, including clouds, shortwave troughs, jet streaks, and more. If they are similar, then confidence should increase that the remaining model forecast output is a viable solution.

Advantages

Can locate shortwaves, jet streaks, vorticity maxima, etc.

Can locate shear zones, building ridges, and other features associated with moderate or greater turbulence events

Can compare dry air sources such as stratospheric intrusions near tropopause folds or subsidence through mixing

Can assist with forecasting the location and timing of dry slots and atmospheric rivers

Disadvantages

The extent of the image is restricted to the model domain

Simulated imagery is only as accurate as the model forecast

The ABI water vapor bands are each different than the current GOES water vapor band, so the clear-sky brightness temperatures will look different by comparison

When is it available and how long is the run?

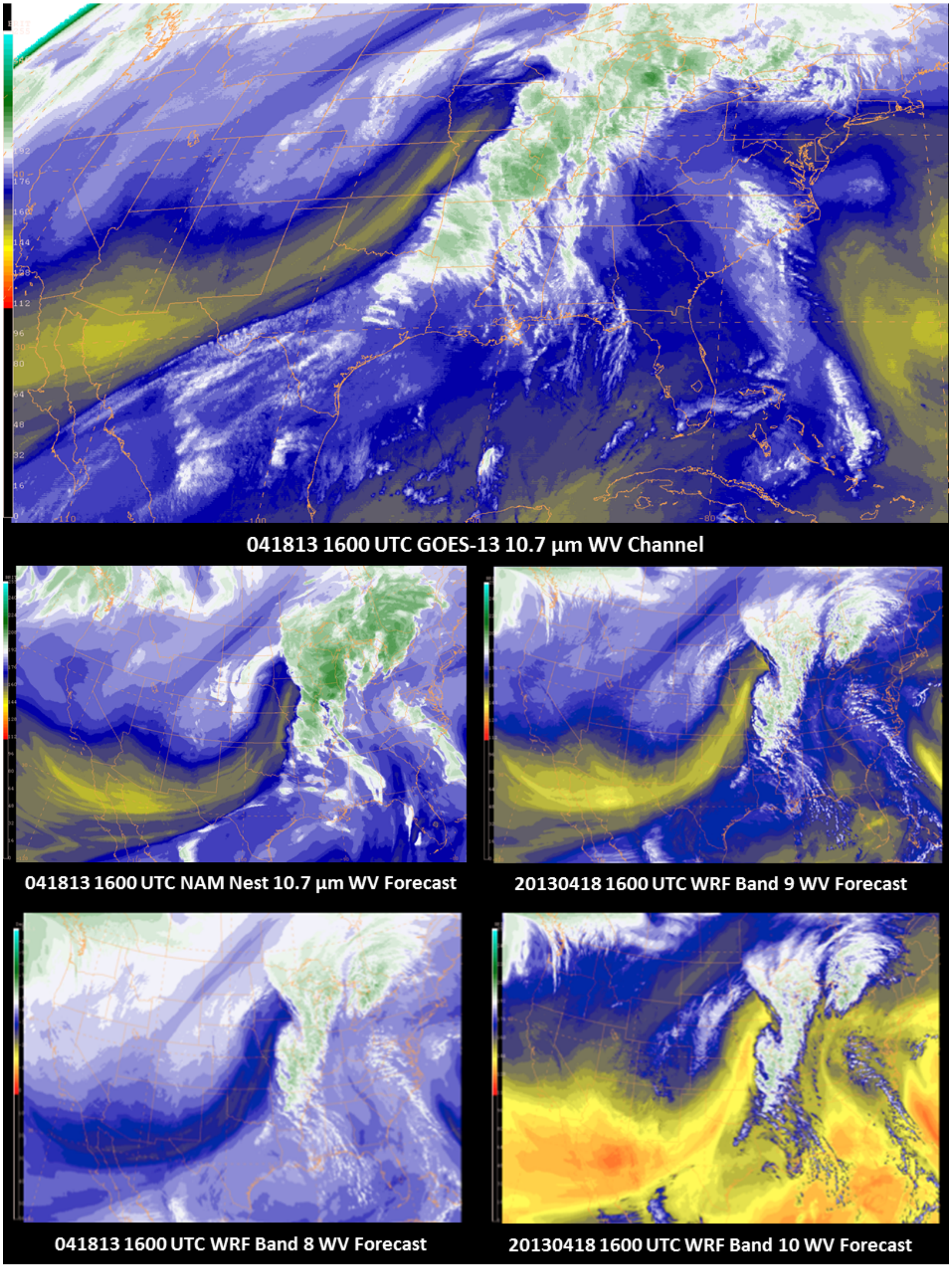
WRF – once a day at ~1100 UTC (0000 UTC run)
NAM – once a day at ~1000 UTC (0000 UTC run)
WRF – 36 hours (1200 UTC Day 1 to 1200 UTC Day 2)
NAM – 60 hours (0900 UTC Day 1 to 1200 UTC Day 3)

Where can I find the data?

WRF-simulated ABI:
IMAGE>SAT>area>goesR>simulated>wrf_arw> (select your favorite band, there are 9 bands to evaluate)

4km nested NAM simulation:
IMAGE>SAT>area>goesR>simulated>nam_nest>b09_wv_mid or b13_ir_clean

Examples of WV



Resources

[Web-based Video: GOES-R 101]() or [GOES-R ABI Training]()

[Web-based Video: Utilizing Synthetic Imagery in Forecasting Severe Thunderstorms]()

Part II: Infrared Bands

What is the WRF/NAM Simulated ABI?

Synthetic satellite imagery provides forecasted radiances in an intuitive display with which users are already familiar, while simultaneously allowing a glimpse into next generation satellite capabilities. Bands and band differences are generated from both the 4 km NSSL WRF-ARW and 4 km NAM Nest models, and can be used to identify specific atmospheric features and monitor the evolution of synoptic and mesoscale systems.

What infrared bands are available?

NSSL WRF-ARW	**Description**
GOES-R Band 11 (8.5 µm)	Cloud-top Phase
GOES-R Band 12 (9.61 µm)	Ozone
GOES-R Band 13 (10.35 µm)	Clean Infrared Longwave
GOES-R Band 14 (11.2 µm)	Infrared Longwave
GOES-R Band 15 (12.3 µm)	Dirty Infrared Longwave
GOES-R Band 16 (13.3 µm)	CO_2 Infrared Longwave
NAM Nest	
GOES-13/15 Band 4 (10.7 µm)	Clean Infrared Longwave

How can simulated imagery be used prior to GOES-R?

Comparing the morning simulated imagery with observed imagery can aid in determining if the model has similar timing and location of synoptic and mesoscale features, including clouds, shortwave troughs, jet streaks, and more. If they are similar, then confidence should increase that the remaining model forecast output is a viable solution.

Advantages

Timing and location of high, middle, and low-level clouds

Locations of clouds within the threshold for the formation of aircraft icing (0 to -25C)

Evolution of convective type cloud features

Monitor the forecasting of cloud-top cooling episodes which could signal heavy precipitation events

Disadvantages

The extent of the image is restricted to the model domain

Simulated imagery is only as accurate as the model forecast

The NSSL WRF under-represents convective cirrus clouds, so model MCS's and thunderstorms won't look as impressive as they do via GOES

When is it available and how long is the run?

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WRF – 36 hours (1200 UTC Day 1 to 1200 UTC Day 2)
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Where can I find the data?

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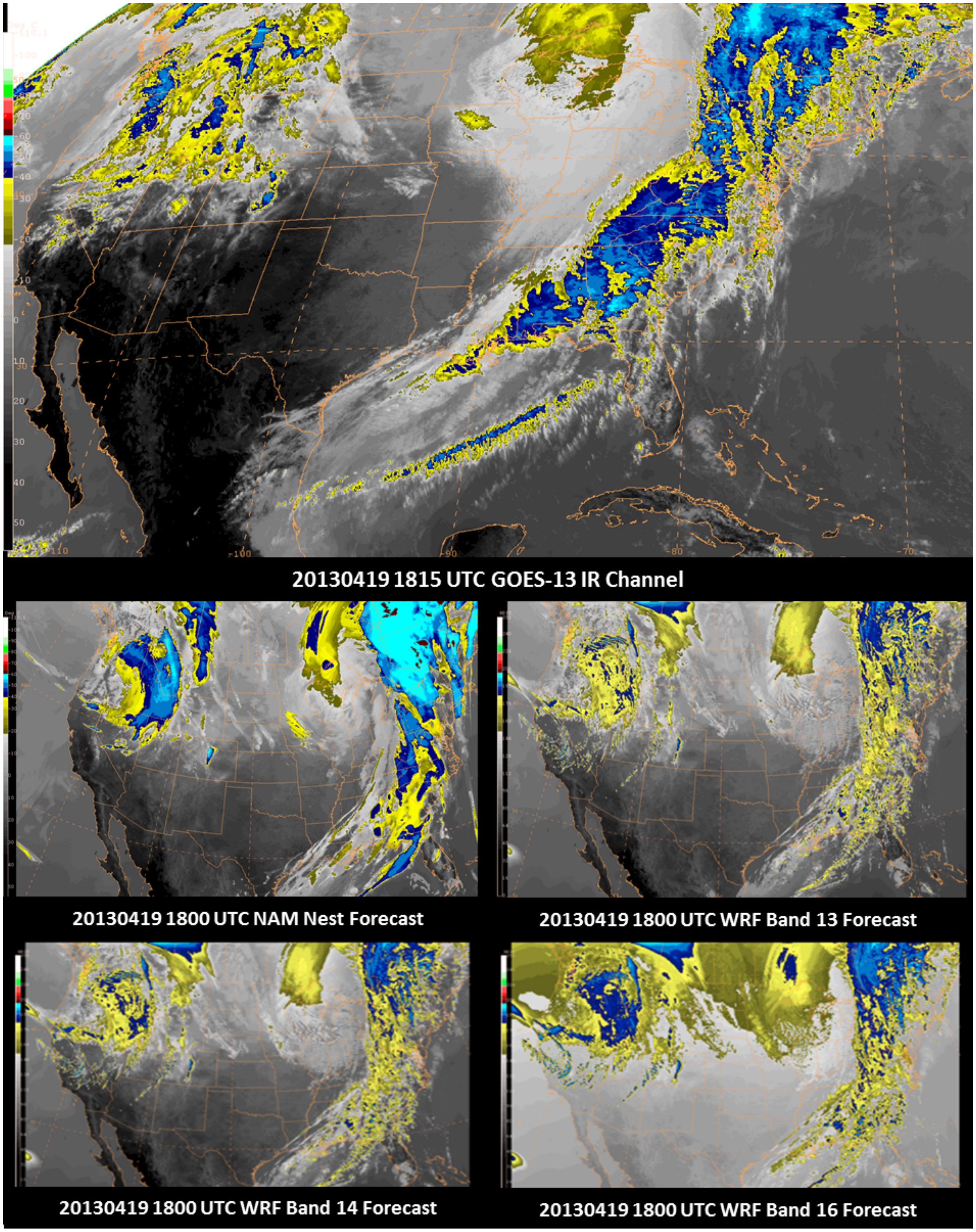
4km nested NAM simulation:
IMAGE>SAT>area>goesR>simulated>nam_nest>b09_wv_mid or b13_ir_clean

Example(s) of IR



Resources

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[Web-based Video: Utilizing Synthetic Imagery in Forecasting Severe Thunderstorms](#)

Part III: Band Differences

What is the WRF/NAM Simulated ABI?

Synthetic satellite imagery provides forecasted radiances in an intuitive display with which users are already familiar, while simultaneously allowing a glimpse into next generation satellite capabilities. Bands and band differences are generated from both the 4 km NSSL WRF-ARW and 4 km NAM Nest models, and can be used to identify specific atmospheric features and monitor the evolution of synoptic and mesoscale systems.

What are the WRF simulated band differences?

The Longwave Difference (LWD) takes advantage of the additional water vapor absorption within the "dirty" IR band (12.3 µm) and uses a difference with the 10.35 µm band to highlight areas with locally higher column water vapor. In clear sky regions, localized maxima in LWD values indicate low-level water vapor convergence along boundaries like warm or cold fronts, drylines, or outflow boundaries.

The Fog Difference uses the legacy 10.35 - 3.9 µm difference (though assumes night time is constant) to generate a model product that identifies areas of low-level liquid water clouds.

WRF-ARW Simulated Band Differences

WRF-ARW Band	Description
GOES-R 3.9 µm – 10.35 µm	Fog Difference: Low-level Cloud and Fog Detection
GOES-R 10.35 µm – 12.3 µm	Longwave Difference: Low-level Water Vapor Convergence Detection

How can simulated imagery be used prior to GOES-R?

Comparing the morning simulated imagery with observed imagery can aid in determining if the model has similar timing and location of synoptic and mesoscale features, including clouds, shortwave troughs, jet streaks, and more. If they are similar, then confidence should increase that the remaining model forecast output is a viable solution.

Advantages

Locations of potential low-level liquid clouds associated with below freezing clouds, indicating a higher likelihood of aircraft icing

In the LWD, areas of red and yellow indicating a local LWD maxima and the possibility for convective development

Disadvantages

High clouds in the fog detection product can obscure lower level clouds and appear as areas darker grays and blacks.

False cloud signatures can occur with the fog detection product as a result of surface emissivities at the wavelengths used in its generation, especially in the southwest U.S.

The LWD product requires the absence of clouds; any cloud interference will give false signals. Clouds are typically shown in blue.

The LWD product will be most useful when actual GOES-R data is flowing

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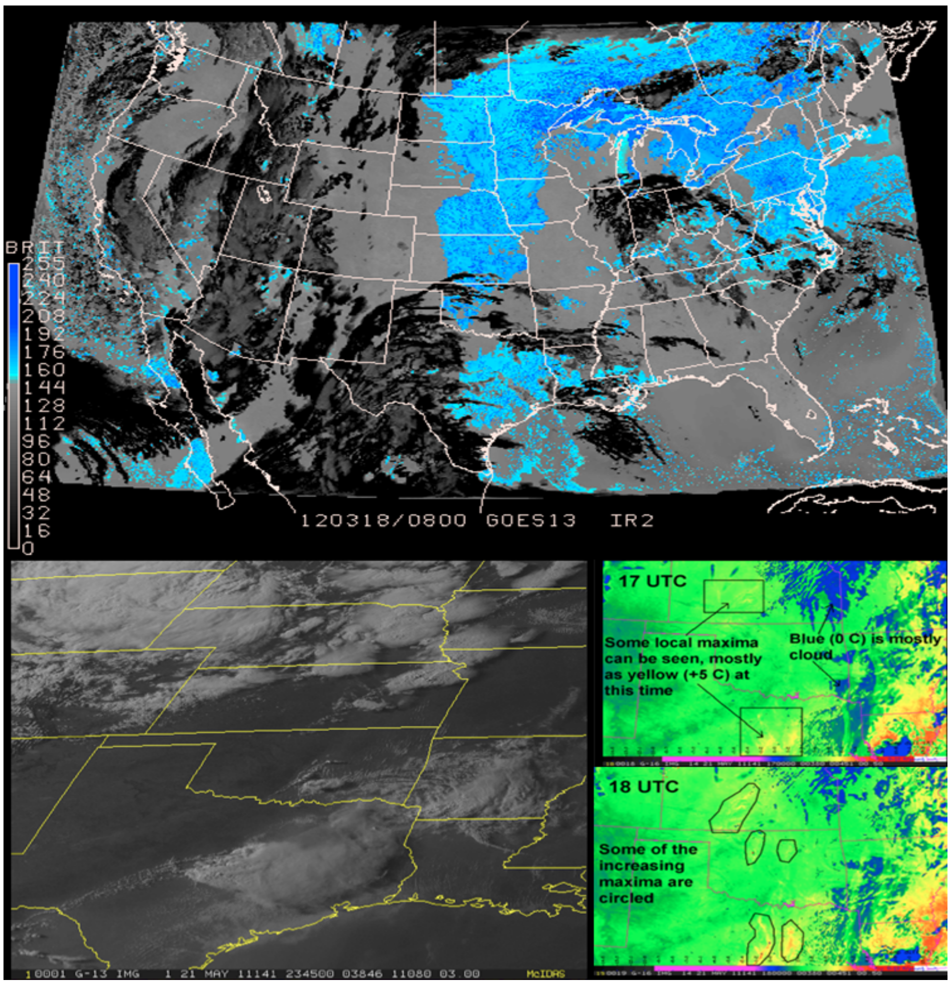
4km nested NAM simulation:
IMAGE>SAT>area>goesR>simulated>nam_nest>b09_wv_mid or b13_ir_clean

Example(s) of Band Difference



Top: (Fog Example) This image from 18 March 2012 shows the NSSL WRF forecast of fog/low clouds. The red circle highlights the DC metro area where thick fog was recorded. The following observation is from Baltimore-Washington International Airport: METAR KBWI 180754Z 12004KT 1/4SM R10/4500VP6000FT FG OVC002 10/09 A3033 RMK AO2 SLP269 T01000094. **Bottom Left:** (LWD Example) 2345 UTC GOES-13 VIS image. **Middle Right:** 20110521 1700 UTC LWD Forecast. **Bottom Right:** 20110521 1800 UTC LWD Forecast. In this example: local maxima in the LWD at 17 and 18 UTC show regions of low-level water vapor convergence, and the VIS image to the left shows that convective clouds have formed in some of these regions by 2345 UTC.

NearCasting Model

What is the NearCasting Model?

The NearCasting Model integrates the hourly full-resolution (10-12 km) information from the 18-channel GOES sounder. Using a Lagrangian approach in which multi-layer moisture information is advected forward in time via RAP modeled wind, this 'model' generates 1-9 hour 'nearcasts' of atmospheric stability indices. These nearcasts were designed to fill the 1-9 hour information gap between long-range numerical forecasts and short-term radar forecasts, and enhance current NWP forecasts by successfully capturing characteristics (gradients, maxima, and minima) that will define the development of convective instability (or stability).

NearCasting Model fields – GOES-13 sounder channels 10 (7.4 µm), 11 (7.0 µm), and 12 (6.5 µm)

500-mb mean layer theta-e
780 mb mean layer theta-e
Vertical theta-e difference
500-mb mean-layer precipitable water
780-mb mean layer precipitable water
Vertical precipitable water difference

How can the Nearcast be used?

- In the difference fields, look for areas of moisture decreasing with height (negative values), indicating regions of convectively instability
- It can identify these same areas in association to pre-existing convection, which may strengthen upon interaction with the indicated convective instability
- Also, moisture increasing with height (positive values) can be used to identify areas of stability that may cause pre-existing convection to weaken

Advantages

- Fills the data gap between short-range obs and long-range NWP guidance
- Uses GOES sounder observations that are not included over land in traditional NWP models
- Moves into areas that can later become obscured by clouds
- Valuable tool to diagnose the accuracy of NWP output fields
- Provides information valuable to the forecast of convective behavior

Disadvantages

- Initial observations are limited to clear-air regions
- RUC model winds used for initializations can include significant initial adjustment noise and must be smoothed
- Though it's Lagrangian design moves data into areas later obscured by clouds, contamination does occur in areas of thick clouds

When is it available and how long is the run?

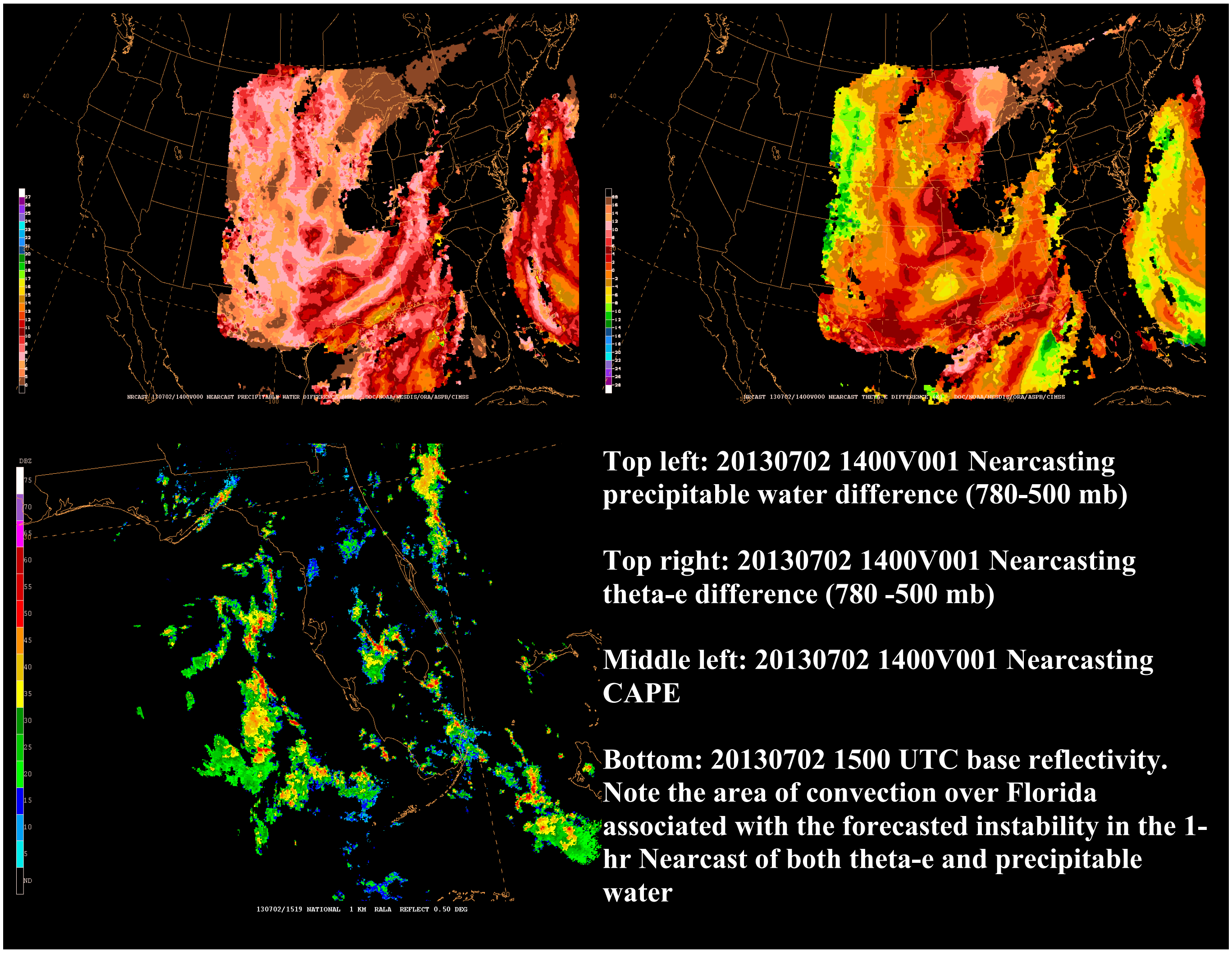
Hourly – 9 hours (F00 – F09)

Where can I find the data?

GRID -> nrcast -> [time] -> nrcas

Resources

[Nearcast training poster] and [Web-based quick-looks and links to web-based training]



GOES-R Convective Intiation

What is the GOES-R Convective Initiation?

The GOES-R Convective Initiation is a satellite-based convective initiation (CI) nowcasting (0-2hr) product that fuses geostationary satellite data and numerical weather prediction model output to produce a probability of CI, where CI is defined as a 35+ dBZ radar echo. Cloud objects are first identified by cloud type and growing cumulus clouds are tracked over consecutive satellite scans.

GOES data utilized includes visible and infrared channels, which are used for cloud typing and determining cloud properties, such as growth, glaciation, and height, and temporal trends in these properties. Model data currently used comes from the RAP and is used to determine environmental information such as CAPE, CIN, lifted index, and several others. Also, the NOAA NWS Operational Hydrologic Remote Sensing Center SNOw Data, Assimilation System (SNODAS) is used to help identify locations of ground snow cover. Snow covered ground can be misidentified by the cloud-typing portion of the algorithm as a cumulus cloud. It is now given its own identifying color (pink) in the strength of signal display.

Convective Initiation – GOES-13 and GOES-15

GOES-13 Convective Initiation Strength of Signal (overlaid with visible imagery)
GOES-15 Convective Initiation Strength of Signal (overlaid with visible imagery)

How can the Cloud-top Cooling be used?

- Pinpoints specific locations within a broad cumulus field that may be conducive to convective initiation
- In conjunction with the Cloud-top Cooling can provide an end to end glimpse into convective initiation and development

Advantages

- Provides situational awareness for locations in which convective initiation may occur, particularly when looking for high probability trends within a broad cumulus field
- The use of NWP model data accounts for environmental factors and allows for a more accurate detection and fewer false alarms
- The snow discrimination piece of the algorithm allows for cloud objects possibly contaminated by snow cover to be identified

Disadvantages

- Can appear "confetti-like", particularly in areas where the convective set-up is not ideal
- Cloud objects cannot be detected in the presence of ciirus clouds
- Cirrus clouds can cause anomalously high probabilities of convection

When is it available and how long is it run?

With each satellite scan (15 or 30 minutes in regular operations, 7 minutes in RSO)

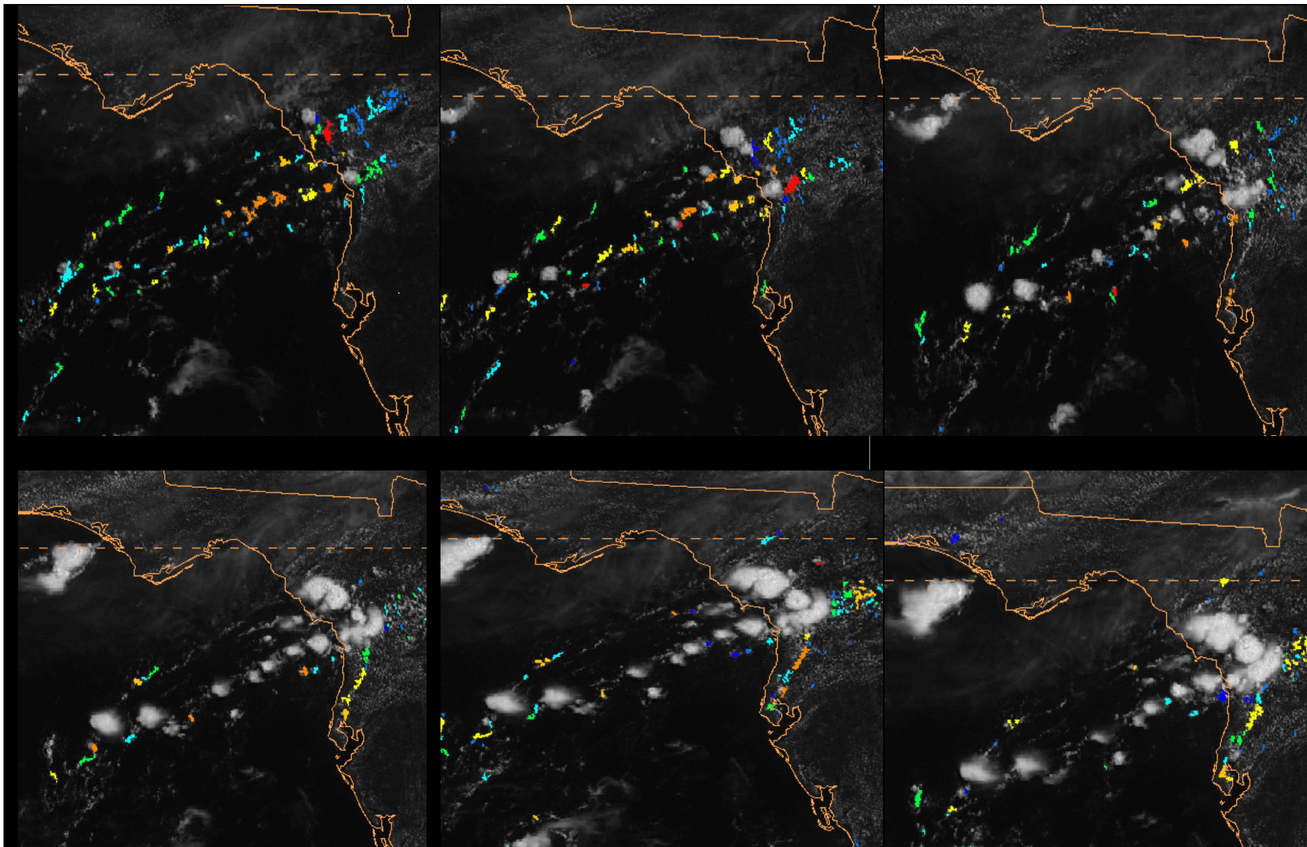
Where can I find the data?

IMAGE -> SAT -> area -> goesR -> convection -> convinit -> (east|west

Resources

[Web-based summary]

[Web-based quick-looks: east] and [Web-based quick-looks: west]



June 27th 1432 – 1615 UTC Convective Initiation

Note the 70+% signals (yellows, oranges, and reds) in the northern portion of the FL peninsula towards the beginning of the time period. The majority of these stronger signals resulted in convective development by 1615 UTC.

Cloud-Top Cooling

What is the Cloud Top Cooling Algorithm?

The Cloud-Top Cooling experimental satellite based product is used to diagnose and nowcast convective initiation and convective cloud-top cooling rate. The algorithm uses GOES imager data to determine immature convective clouds that are growing vertically and hence cooling in the infrared satellite imagery. Additionally cloud phase information is utilized to identify cloud maturity by deducing whether the cooling clouds are immature water clouds, mixed phase, or ice-topped clouds.

Cloud-top Cooling – GOES-13 and GOES-15

GOES-13 Instantaneous Cloud-top Cooling rate (K per 15 min)
GOES-15 Instantaneous Cloud-top Cooling rate (K per 15 min)
GOES-14 SRSOR Cloud-Top Cooling rate (K per 5 min)

How can the Cloud-top Cooling be used?

- Provides situational awareness in identifying potential areas of strong convective development
- Provides extra information on developing convection in areas with poor radar coverage (i.e. gaps between radars, large bodies of water, etc.)
- Can be used with the GOES-R CI to provide an end-to-end glimpse of convective development and initiation
- Has been shown to provide lead-time for the development of robust convective cores and associated radar features (18dBZ echo tops, CG lightning, etc. See Table 1 below)

Advantages

- Diagnoses developing convective clouds in clear, partly cloudy, or thin cirrus (day only) scenes)
- Is day/night dependent because of its reliance on only infrared channels
- The product is available approximately 2 minutes after initial code execution
- Operates on both rapid (7.5 min) and operational (15 to 30 min) scanning patterns.
- Large spatial coverage (GOES-E and GOES-W CONUS areas)

Disadvantages

- Fast moving clouds can occasionally induce false alarms
- False alarms may increase with GOES 30 minute full-disk scans
- Radar echo/cloud-to-ground lighting lead-time may be small with rapidly developing thunderstorms.

When is it available and how long is the run?

With each satellite scan (15 or 30 minutes in regular operations, 7 minutes in RSO)

Where can I find the data?

GRID -> (cinit|cinitw|cinitsrsor) -> [time] -> cinit -> CTC2INST:Cooling_rate

Resources

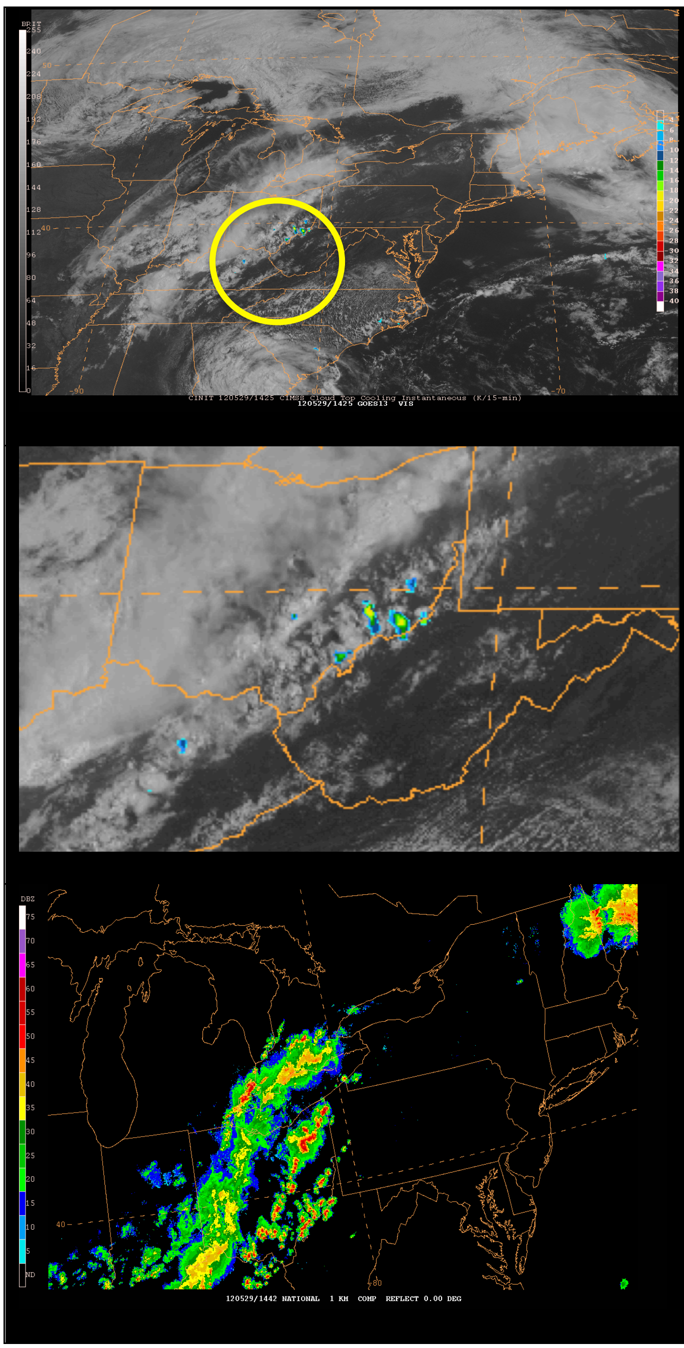
Web-based training and Articulate version

Web-based quick-looks

Table 1. CTC rates vs. NEXRAD radar parameters (Sieglaff et al. 2012)

	Weak CTC > -10 K	**Moderate -10 K >= CTC >-20 K**	**Strong CTC <= -20 K**
Composite Reflectivity	45 dBZ	50 dBZ	55 dbZ
18 dBZ Echo Top Height	40 kft	46 kft	50 kft
30 dBZ Echo Top Height	35 kft	39 kft	45 kft

	Lead time given a strong CTC rate (<= -20 K)
Composite Reflectivity	~15 min; 55 dBZ ~25 min; 60 dBZ 60+ min; 65+ dBZ
18 dBZ Echo Top Height	~5-8 min; to 40 kft ~20 min; 50+ kft
30 dBZ Echo Top Height	~10 min; 20-30 kft ~30 min; 50 kft



Top left: 1425 UTC Cloud-top Cooling

Top right: 1440 UTC Cloud-top Cooling

Middle left: 1425 UTC zoomed CTC

Middle right: 1440 UTC zoomed CTC

Bottom left: 1442 UTC base reflectivity

Note the cooling signals in SE Ohio prior to the development of scattered cells in the reflectivity.

Overshooting Top Detection – Quick Guide

Why is the Overshooting Top Detection (OTD) algorithm important?

Overshooting tops (OTs) often indicate the region of a thunderstorm with the highest potential for heavy rain or potential severe weather. During the day time, visible imagery would likely be the most useful source of information for locating overshooting tops. Locating OTs at night can be a challenge using conventional GOES-13 4 km IR and WV channels. Overlaying the OTD or OT Magnitude products on this imagery can vastly improve diagnosing areas of potential heavy rain or severe weather over land or in maritime regions.

Algorithm Methodology: How are the OTs determined and how are they represented?

Product	Output	Scale	Description
OTD	Binary (yes or no)	≥ 6 K	Indicates OT location
OT Magnitude	Color coded temperature difference	-6 K to -20 K	Indicates OT location and provides information on temperature difference between OT and surrounding cirrus shield

Operational Significance: When to use?

- The OTD algorithm indicates an OT when the -6 K threshold is reached between the OT and the surrounding cirrus canopy.
- It offers a more consistent day/night OT detection capability with greater accuracy than the existing operational OT detection method based on the 6.5 µm water vapor (WV) minus 10.7 µm infrared (IR) window channel brightness temperature (BT) difference
- Code is flexible and operates on both rapid scan (5-min) and operational (15 to 30-min) scanning patterns
- The product is available from GOES-13 and GOES-15, providing continuous coverage over the CONUS.
- Product shows strong relationships with occurrences of cloud-to-ground lightning, aircraft turbulence, maximum in-storm radar reflectivity, and severe weather reports

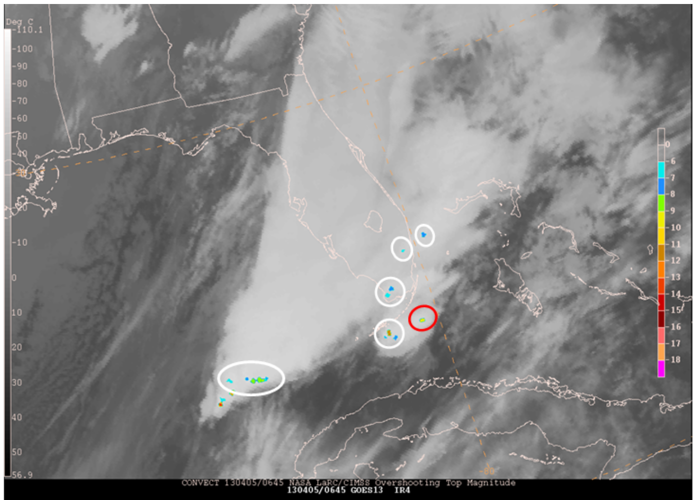
Product Limitations: When not to use?

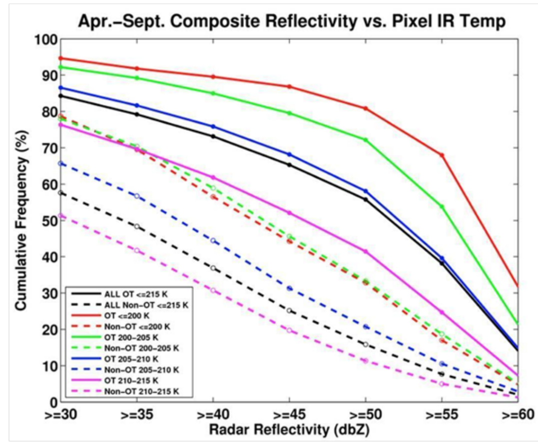
- Marginal OT events with an overshoot magnitude of < 0.5 km and/or little to no horizontal IR window BT gradient may **NOT** be detected by this method
- OT events with IR window temperatures $>$ 217.5 K will not be detected
- Since largest observed OT is < 15 km in diameter, algorithm settings dictate that OT detections must be > 15 km away from other OT detections. Only one of two OTs will be detected if the two are spaced less than 15 km apart
- Locations within a very cold, non-convective cirrus plume exhibiting significant texture in the IR window BT field can be misclassified as an OT
- Very cold cirrus anvil edges can be misclassified as an OT

Product Availability

- The product is available on the UW-CIMSS ADDE (and/or LDM) server approximately 45 seconds after the algorithm code is executed, as a gridded file.
- Forecasters can find the product in NAWIPS in the following locations:
- **GRID -> (cinit|cinitw) -> (date/time) -> cinit -> Overshoot_detection**
- **GRID -> (cinit|cinitw) -> (date/time) -> cinit -> Overshoot_Magnitude**

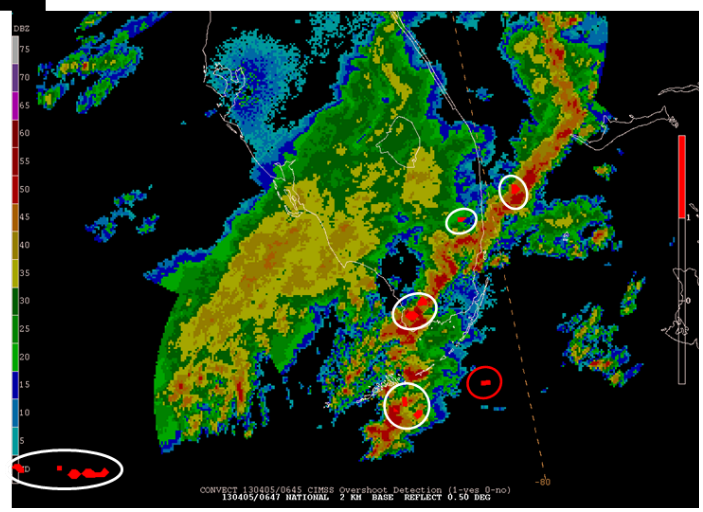
Example(s) of OT Magnitude and Radar





Frequency of Overshooting Top Detection Near Confirmed Severe Weather Events: April-September 2004-2009

Severe Weather Type	# Severe Reports	OT Match %
Tornado	4,684	56.2%
Severe Wind	52,743	58.4%
Large Hail	56,114	51.3%
Any Type	113,541	54.8%



Top Left: GOES-13 IR image taken at 0645Z on April 5th, 2013, showing a convective line across southern Florida. The OT magnitude product is overlaid; positive detects are circled in white, false detects are circled in red. **Top Right:** A comparison of radar reflectivities with cumulative frequency of OT detection based on various IR BTs during an April - September timeframe. **Bottom Left:** Frequency of overshooting top detection near confirmed severe weather events: April-September 2004-2009. **Bottom Right:** National 2-kilometer base reflectivity image taken at 0647Z on April 5th, 2013, showing a convective line across southern Florida. The OTD product is overlaid; positive detects are circled in white, false detects are circled in red.

Additional Resources

Training PPT for WPC and SAB

Visit View session with a voice over by Scott Lindstrom (UW-SSEC/CIMSS)

GOES-R User Readiness Overview

Comprehensive Document on the Overshooting Top Algorithm

Product Fact Sheet

GOES-R Cloud Algorithms

What are the GOES-R Cloud Height Algorithms?

The Cloud Height Algorithms uses satellite retrievals to calculate various cloud-top microphysical properties not available via any ground-based instrumentation such as height, pressure, temperature, phase, and emissivity. Not only can these properties be used as standalones for an additional situational awareness tools, but they are also utilized in many of the other GOES-R derived products including, but not limited to, Fog and Low Stratus, the Flight Icing Threat, and Cloud-top Cooling.

NearCasting Model – GOES-13 sounder channels 10 (7.4 µm), 11 (7.0 µm), and 12 (6.5 µm)

Cloud-top Height
Cloud-top Temperature
Cloud-top Phase
Cloud mask
Emissivity

How can the Cloud Height Algorithms be used?

- Cloud phase can be used to assist in forecasts of icing (identification of supercooled droplets) and convection (identification of storm maturity)
- Cloud height can be used to identify levels at which threats such as icing or convection may be occurring
- The cloud mask is used to identify thin cirrus through which rapidly growing convective clouds or other cloud features can still be identified
- All of the algorithms can be used in support of other derived products such as Cloud-top Cooling, the Flight Icing Threat, and Fog and Low Stratus

Advantages

- Allows forecasters to become familiar with microphysical properties often utilized in the generation of other GOES-R derived products
- Provides valuable information on cloud properties not available via ground-based instrumentation
- Can be used together to get an idea of cloud structures within larger scale systems

Disadvantages

- Information is only for cloud tops. Therefore thick cirrus clouds can obscure cloud features at lower levels
- Not particularly useful as a standalone. Maximum utilization of these tools is found when they are used with other cloud properties or GOES-R derived products.

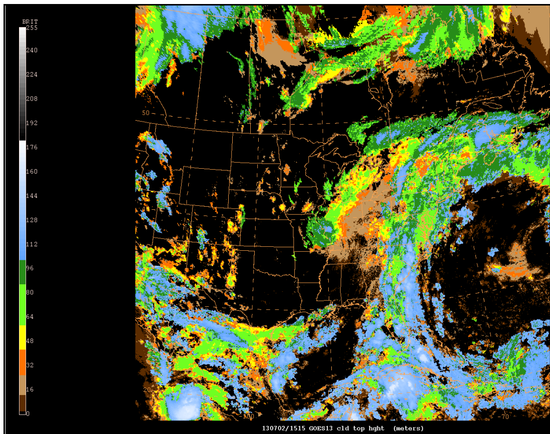
When is it available?

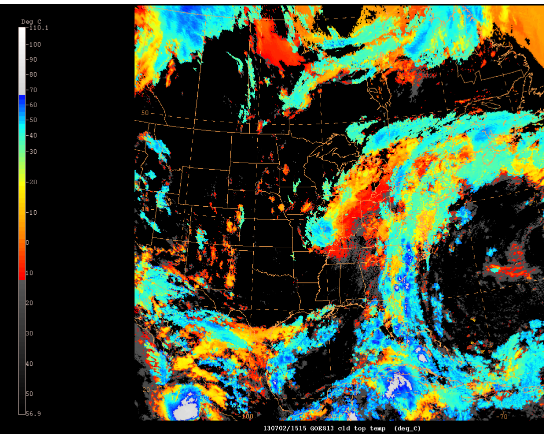
With each GE/GW satellite scan; ~15 minutes with routine operations and ~7 minutes with RSO

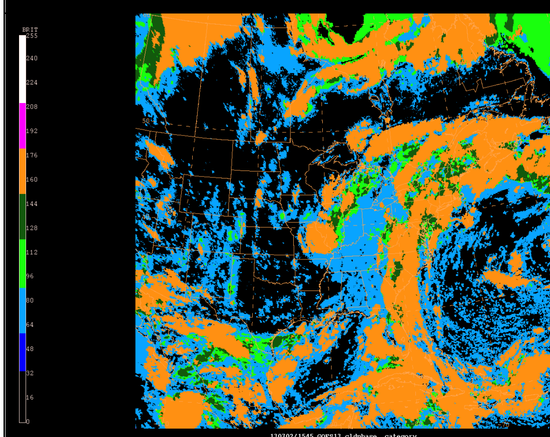
Where can I find the data?

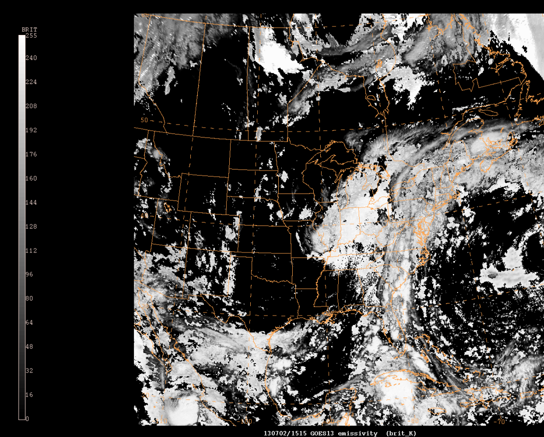
IMAGE -> sat -> area -> goesR -> cloudprop

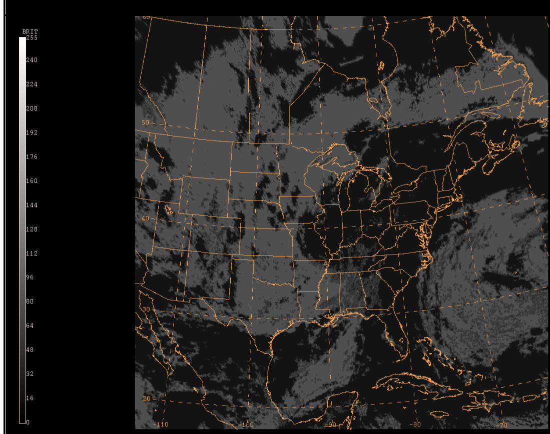
Resources











Top left: 20130702 1515 UTC cloud top height

Top right: 20130702 1515 UTC cloud top temp

Middle left: 20130702 1545 UTC cloud phase

Middle right: 20130702 1515 UTC emissivity

Bottom right: 20130702 1545 UTC cloud mask

Total Lightning Quick Guide by NASA SPoRT – National Centers

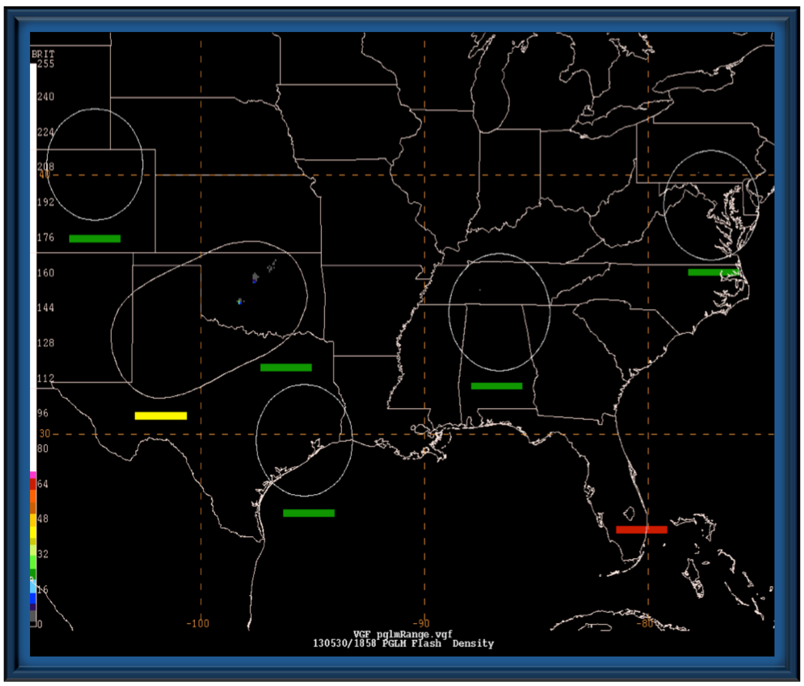
What is Total Lightning?

Total lightning observes both cloud-to-ground strikes and intra-cloud flashes. On average, upwards of 90% of all lightning flashes in a given thunderstorm are intra-cloud flashes. As a result total lightning provides far more information than National Lightning Detection Network data alone. Furthermore, the amount of total lightning is related to a storm's overall updraft strength in the mixed phase region. Total lightning is currently available from ground-based lightning mapping arrays (LMAs). In the GOES-R era, total lightning will be available from the Geostationary Lightning Mapper (GLM) that will provide almost full disc coverage.

Product Categories

NASA SPoRT provides two total lightning product sets. These include the ground-based LMA observations at a 1-2 km resolution, and SPoRT's pseudo-geostationary lightning mapper (PGLM) product suite with 8 km resolution. The PGLM demonstrates future GLM capabilities. The operational uses below are valid for either product set:

Operational Uses



Advantages of Total Lightning

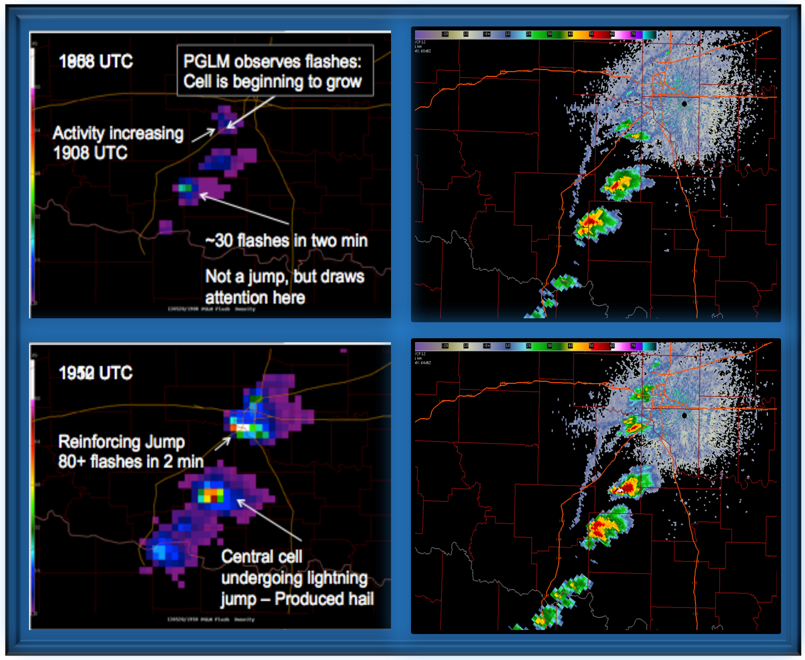
- More observations than National Lightning Detection Network data alone.
- Spatial extent of a lightning flash, i.e. it is not a point observation.
- Sub-radar volume scan updates of 1-2 minutes.
- Total lightning is non-linearly related to a storm's updraft strength in the mixed phase region.
    - More total lightning equals a much stronger storm updraft and vice versa.
    - Special case: Lightning Jumps are often precursors to severe weather.
    - Can precede severe weather by 10-20 minutes.

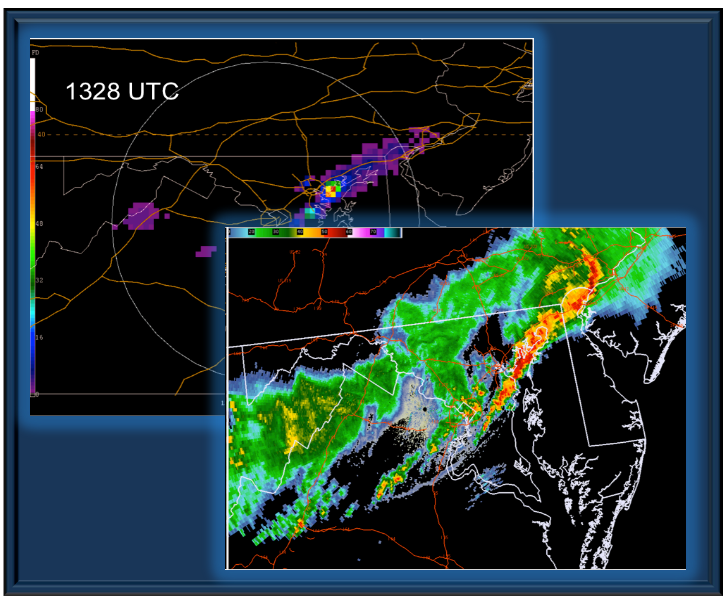
First Cloud-to-Ground Lightning Strike Lead Time

- On average, 90% of all lightning flashes are intra-cloud.
- Approximately 80% of thunderstorms initiate with an intra-cloud flash.
- Often, the first intra-cloud flash will precede the first cloud-to-ground strike by 5-10 minutes.
- Can enhance Airport Weather Warnings, Terminal Aerodrome Forecasts, and improve lightning safety.

Lightning Jumps and Severe Weather

- Most common use of total lightning observations.
- Lightning jumps are large and rapid (within 10 minutes) increases of total lighting.
- Often precede severe weather by 10-20 minutes on average.
- Lightning jumps often "tip the scales" for forecasters determining whether or not to issue a warning.
- Provides situational awareness of which storms are strengthening / weakening or possibly becoming severe.
- Provides warning decision support.





Spatial Extent of Lightning Flashes

- Total lightning is not a point source and provides a better observation of the lightning threat.
- Most lightning remains within 10 miles of the core of a thunderstorm.
- Some flashes may extend many tens of kilometers.
- Visualization of total lightning can be used to demonstrate lightning's threat and the importance to remain indoors for 30 minutes after the last lightning strike was seen or heard.

Where can find the PGLM in AWC systems?

IMAGE -> SAT -> area -> goesR -> convection -> lightning
**Use the range ring file with this imagery: VGF -> pglmRangeold.vgf

Resources

Operational applications (http://nasasport.wordpress.com/) and what is total lightning:
(http://weather.msfc.nasa.gov/sport/lma/, http://weather.msfc.nasa.gov/sport/goesrpg/pglm.html, and http://weather.msfc.nasa.gov/sport/training/).